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(54) **VISUAL EXPLORATION OF MULTIDIMENSIONAL DATA**

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G06F 3/0482 (2013.01)
G06T 11/20 (2006.01)

(52) **U.S. Cl.**
CPC ***G06F 3/0484*** (2013.01); ***G06F 3/0482*** (2013.01); ***G06T 11/206*** (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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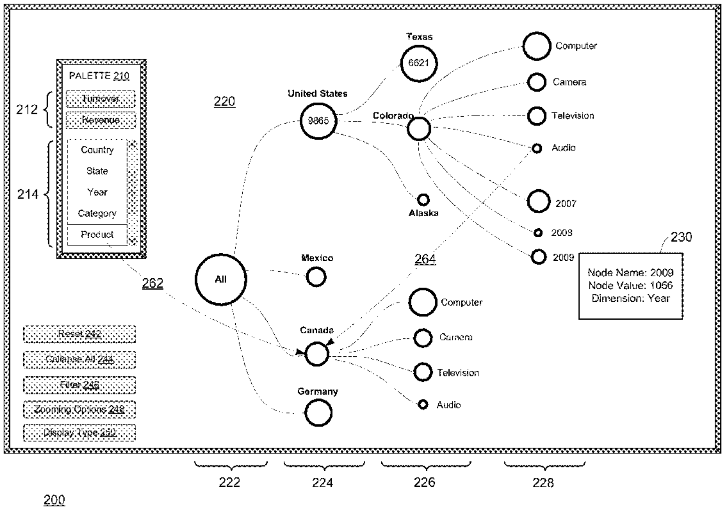
(57) **ABSTRACT**

Embodiments of the present disclosure provide systems and methods for displaying multidimensional data in a decomposition tree. The decomposition tree may include a plurality of levels, with the first level including a parent node representing the multidimensional data and the subsequent levels including one or more nodes representing a subset of the data repressed by the parent node along dimensions selected by a user. The decomposition tree may include nodes belonging to the same dimension in different levels of the decomposition tree. A node in the decomposition tree may be split by more than one dimension inside a same subsequent level.

20 Claims, 6 Drawing Sheets



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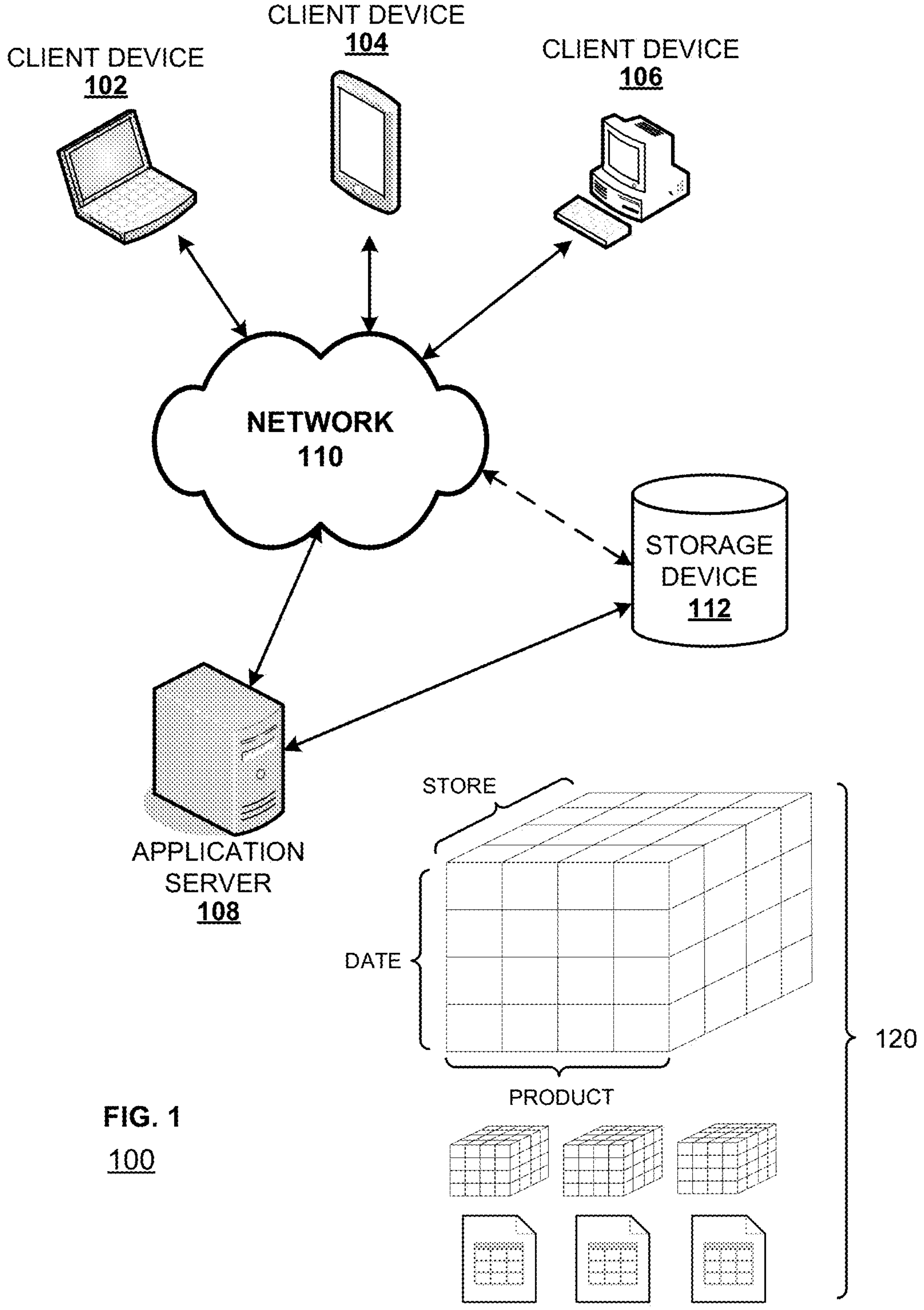

CLIENT DEVICE
102
CLIENT DEVICE
104
CLIENT DEVICE
106
NETWORK
110
STORAGE
DEVICE
112
APPLICATION
SERVER
108
STORE
DATE
PRODUCT
120

FIG. 1

100

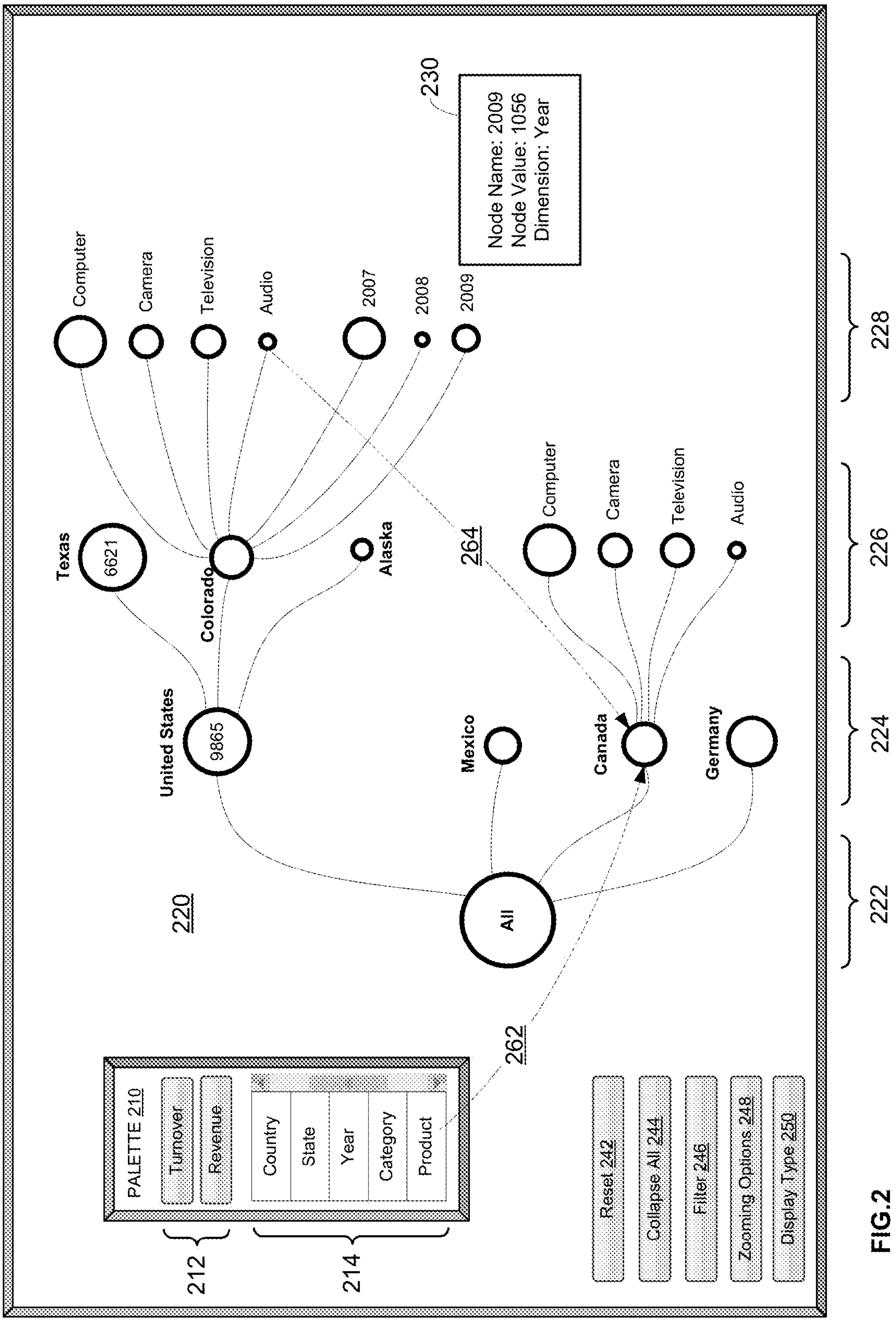

PALETTE 210
Turnover
Revenue
Country
State
Year
Category
Product
212
214
262
220
All
United States
9865
Mexico
Canada
Germany
Texas
6621
Colorado
Alaska
Computer
Camera
Television
Audio
2007
2008
2009
264
Computer
Camera
Television
Audio
230
Node Name: 2009
Node Value: 1056
Dimension: Year
222
224
226
228
Reset 242
Collapse All 244
Filter 246
Zooming Options 248
Display Type 250

FIG.2
200

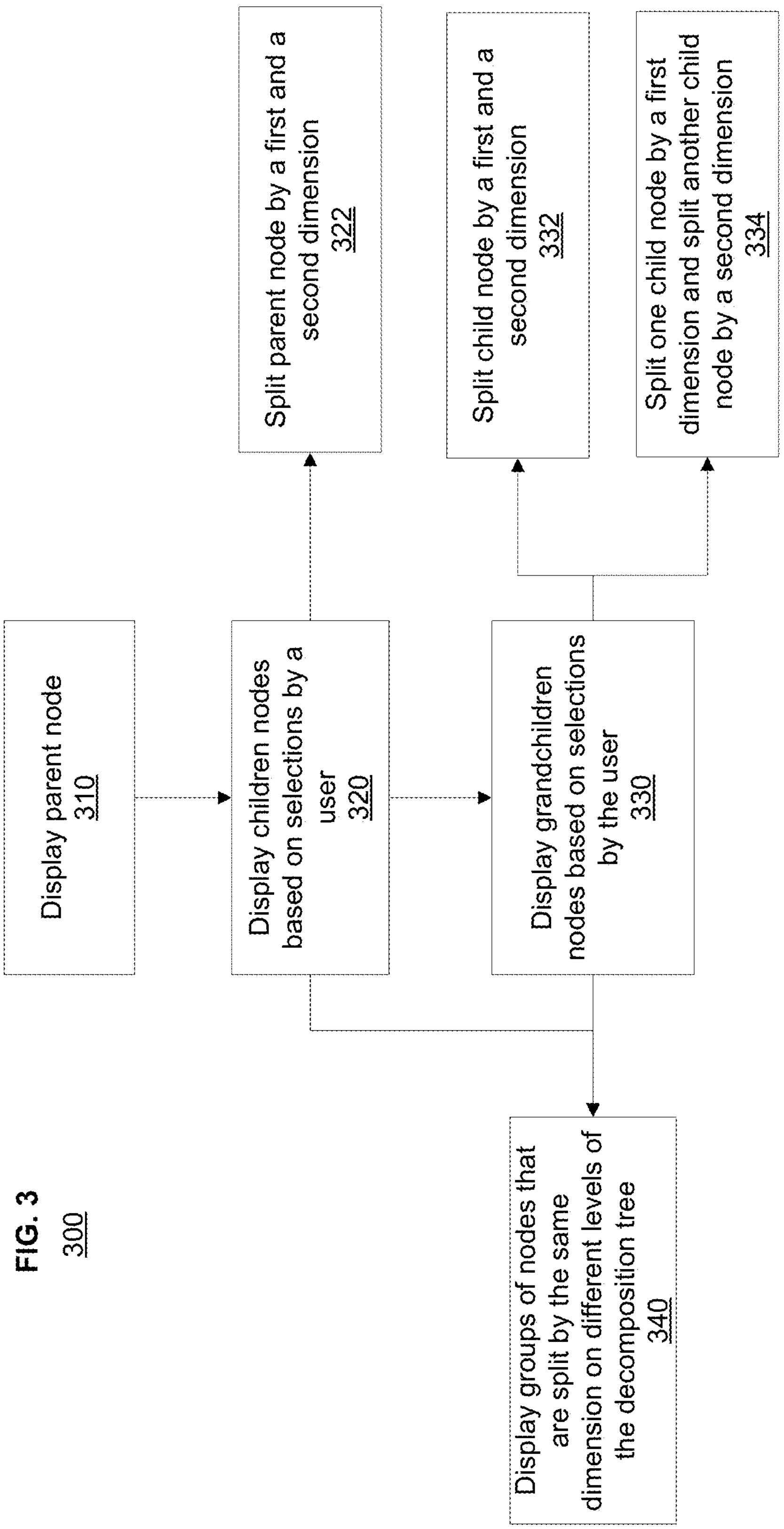

Display parent node
310
Display children nodes based on selections by a user
320
Display grandchildren nodes based on selections by the user
330
Split parent node by a first and a second dimension
322
Split child node by a first and a second dimension
332
Split one child node by a first dimension and split another child node by a second dimension
334
Display groups of nodes that are split by the same dimension on different levels of the decomposition tree
340

FIG. 3
300

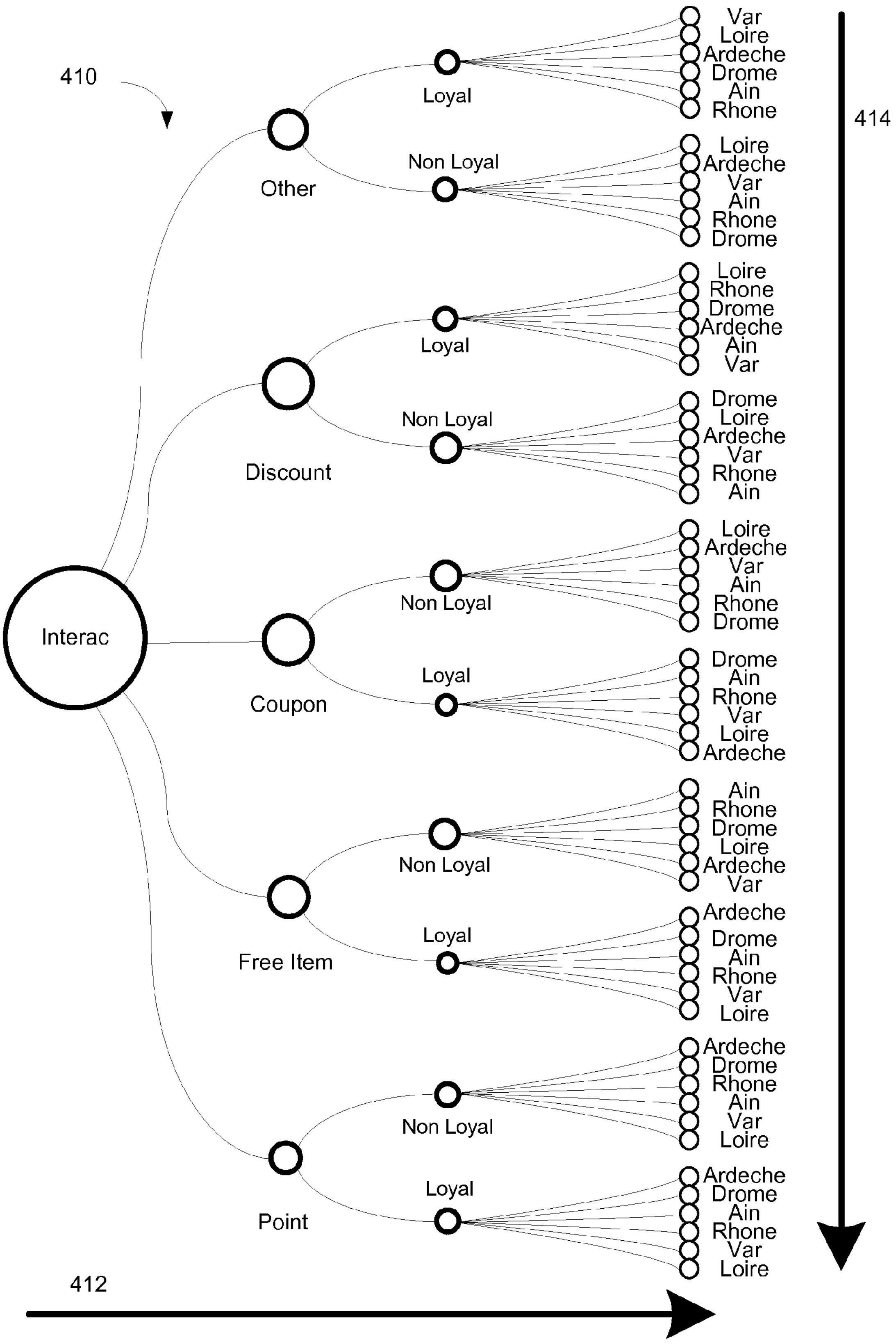
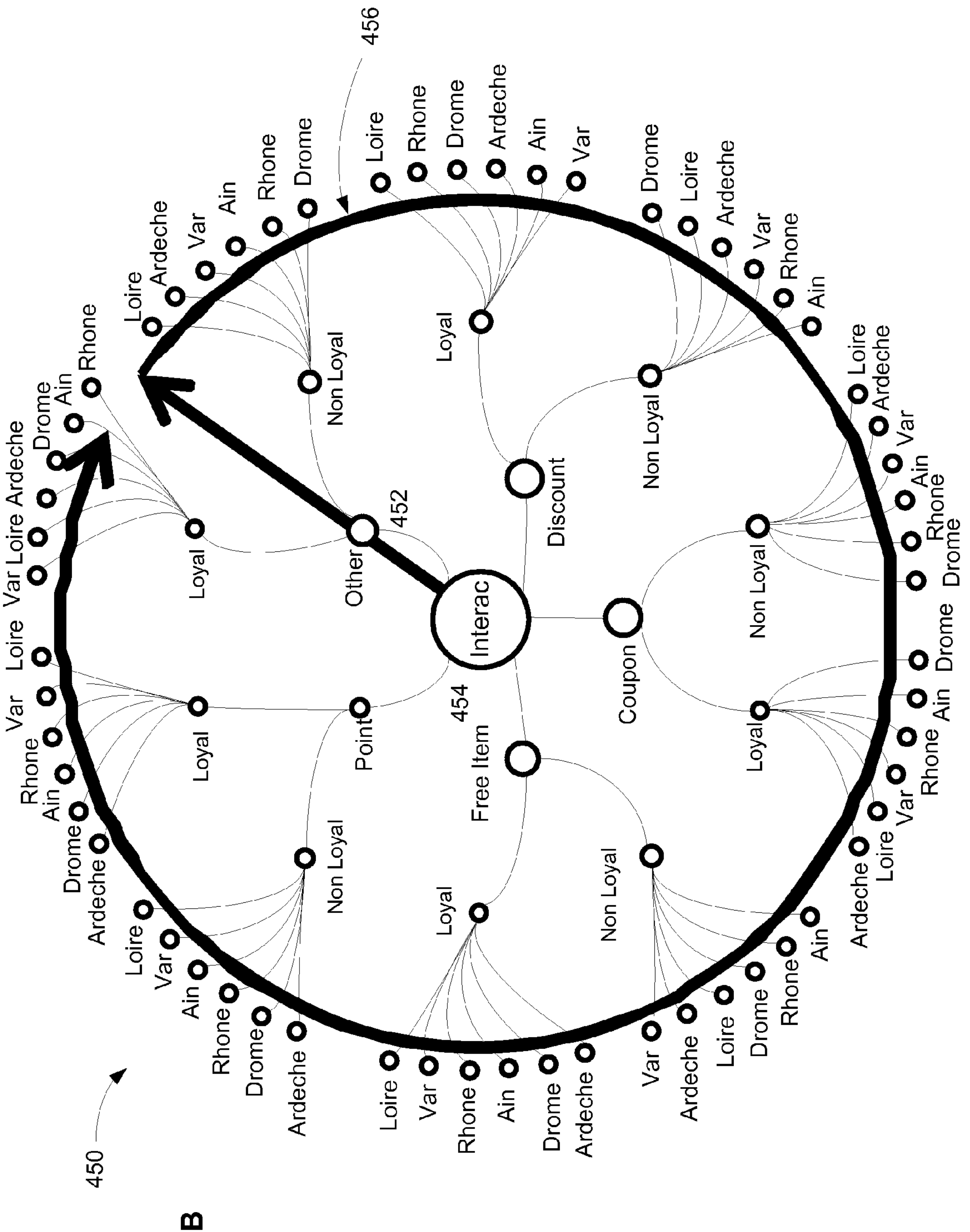

410
Interac
Other
Loyal
Var
Loire
Ardeche
Drome
Ain
Rhone
Non Loyal
Loire
Ardeche
Var
Ain
Rhone
Drome
Discount
Loyal
Loire
Rhone
Drome
Ardeche
Ain
Var
Non Loyal
Drome
Loire
Ardeche
Var
Rhone
Ain
Coupon
Non Loyal
Loire
Ardeche
Var
Ain
Rhone
Drome
Loyal
Drome
Ain
Rhone
Var
Loire
Ardeche
Free Item
Non Loyal
Ain
Rhone
Drome
Loire
Ardeche
Var
Loyal
Ardeche
Drome
Ain
Rhone
Var
Loire
Point
Non Loyal
Ardeche
Drome
Rhone
Ain
Var
Loire
Loyal
Ardeche
Drome
Ain
Rhone
Var
Loire
414
412

FIG. 4A


450
452
454
456
Interac
Other
Discount
Coupon
Free Item
Point
Loyal
Non Loyal
Loyal
Non Loyal
Loyal
Non Loyal
Loyal
Non Loyal
Loyal
Non Loyal
Loyal
Var
Loire
Ardeche
Drome
Ain
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Ardeche

FIG. 4B

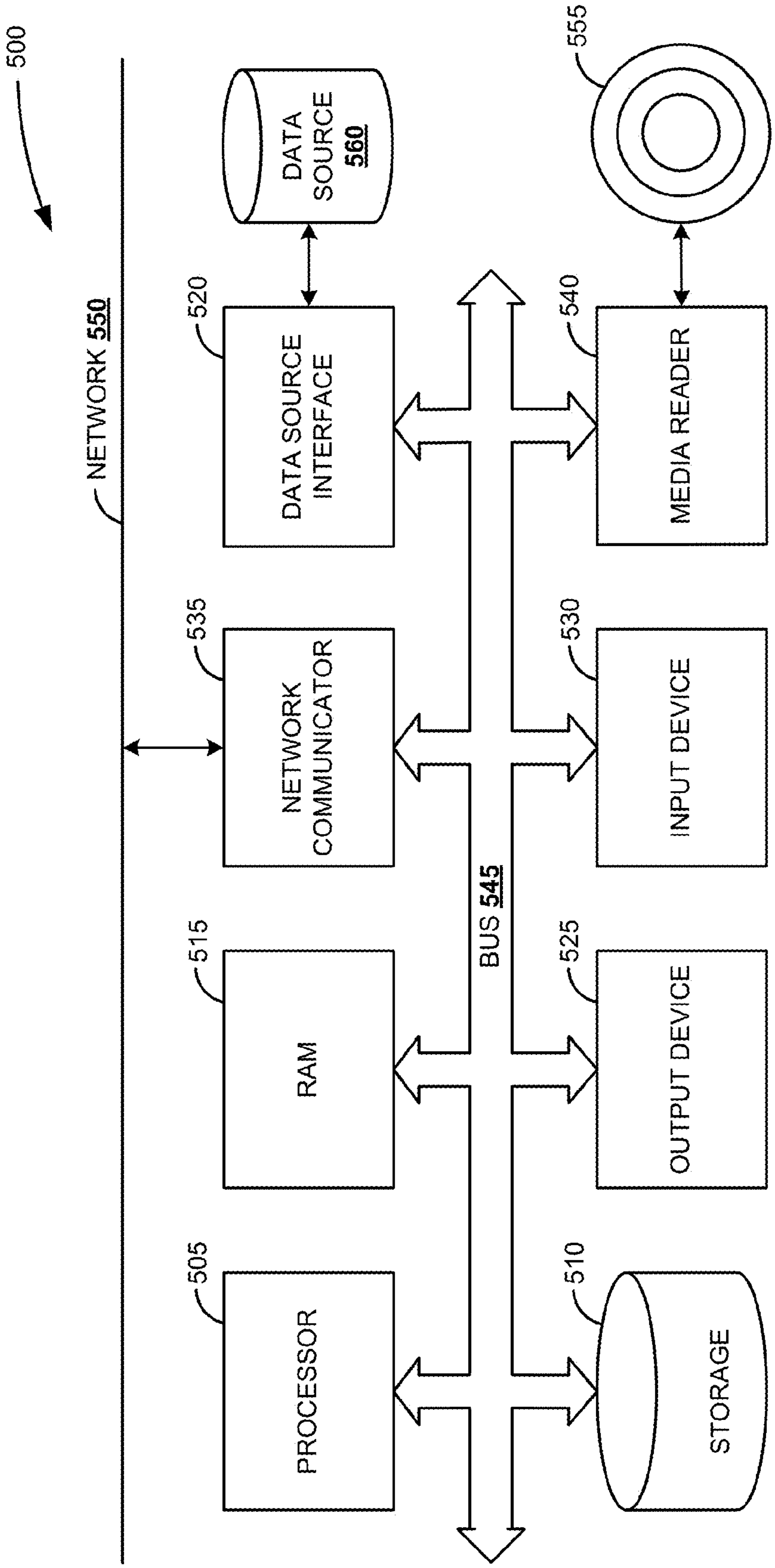
500
NETWORK 550
DATA SOURCE 560
555
520
DATA SOURCE INTERFACE
540
MEDIA READER
535
NETWORK COMMUNICATOR
530
INPUT DEVICE
BUS 545
515
RAM
525
OUTPUT DEVICE
505
PROCESSOR
510
STORAGE

FIG. 5

VISUAL EXPLORATION OF MULTIDIMENSIONAL DATA

BACKGROUND

In today's competitive markets, organizations need to make quick business decisions (e.g., identifying opportunities, strategy and market advantages) based on constantly changing conditions. Collecting, analyzing and displaying the data are integral parts of making such decisions. However, as the volume of data that an organization collects, analyzes and displays is increased, it becomes more difficult for the organization to make quick and accurate decisions. Even after the large volume of data is collected and analyzed, it is still challenging to display this data to a manager of the organization in an easy to understand and visually pleasant way.

Online analytical processing (OLAP), multidimensional data models and relations database models have improved the way organizations view the data by summarizing the data from the organizations database. However, even with these models managers of organizations are not always provided with easy to use and interactive methods to view and browse data that provides a good picture of the organizations positions or capabilities.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings illustrate the various embodiments and, together with the description, further serve to explain the principles of the embodiments and to enable one skilled in the pertinent art to make and use the embodiments.

FIG. **1** is a block diagram illustrating an example embodiment of a networked environment in which a client device connects to an application server via a network.

FIG. **2** illustrates a user interface displaying a hybrid decomposition tree according to an embodiment of the present disclosure.

FIG. **3** illustrates a method of displaying a decomposition tree according to an embodiment of the present disclosure.

FIGS. **4**A and **4**B illustrate a linear decomposition tree and a polar decomposition tree according to an embodiment of the present disclosure.

FIG. **5** is a block diagram of an exemplary computer system that may be used with the embodiments of the present disclosure.

DETAILED DESCRIPTION

Embodiments of the present disclosure provide systems and methods for displaying multidimensional data in a decomposition tree. The decomposition tree may include a plurality of levels, with the first level including a parent node representing the multidimensional data and the subsequent levels including one or more nodes representing a subset of the data repressed by the parent node along dimensions selected by a user. The decomposition tree may include nodes belonging to the same dimension in different levels of the decomposition tree. A node in the decomposition tree may be split by more than one dimension inside a same subsequent level.

The decomposition tree allows users to view and gain insight from large and complex datasets. The decomposition tree according to the embodiments of the present disclosure provides an easy way to visualize and explore the data and allows users to easily customize the display of the data. The

user can display data that is needed to make a decision without having to display data that may clutter the decomposition tree. By allowing the user options to split a single node by different dimensions and to display nodes split by different dimension in a same level of the decomposition tree, the user may generate a customized decomposition tree that is not restricted to a rigid hierarchical mapping between the tree levels and dimensions.

FIG. **1** is a block diagram illustrating an example embodiment of a networked environment **100** in which a client device **102**, **104** or **106** connects to an application server **108** via a network **110**. The client device **102**, **104**, or **106** may execute applications provided on the respective client device **102**, **104** or **106** or may execute web-based applications provided by the application server **108** via the network **110**. The applications executed by the client device **102**, **104**, or **106** may be used to display data **120** stored in the application server **108** and/or the data storage device **112**. The data may be displayed on the client device **102**, **104**, or **106** according to one or more of the embodiments described below. Based on the displayed data a user may make business decisions for an organization. The user may issue instructions for the organization via the client device **102**, **104**, or **106**.

The client device **102**, **104**, **106** may include, for example, a mobile device (e.g., mobile phone or a smart phone), a personal computer, a tablet, a terminal device, or a personal digital assistant (PDA). The client device **102**, **104**, **106** may include an input device (e.g., a touch screen, a touch pad, a mouse or a keyboard) to receive commands from a user.

The data storage device **112** may be a data warehouse. The data warehouse may perform data cleaning, integration, transformation and refreshing. The data storage device **112** may be an in-memory database (e.g., SAP® HANA database).

The data **120** may be stored and analyzed based on the multidimensional data models and/or relational database models. Multidimensional data may be analyzed via analytical operations (e.g., Online Analytical Processing (OLAP)) to provide a quick and interactive means of data analysis. OLAP operations may provide the data analysis on a higher level than the traditional relational database models. The results of OLAP may be referred to as OLAP cube (e.g., multidimensional OLAP Cube).

The data may be grouped into dimension and measure categories. The measure may be a key figure representing a value (e.g., consumer count, amount of sales, revenue or cost). The dimension may include data elements or members that are used to group, filter and/or label the measures (e.g., by store, by month, or by product). As shown in FIG. **1**, the OLAP cube may include multiple dimensions (e.g., product, date and store dimensions). When the data is accessed by a user in response to a request, the request may split a measure by zero, one or multiple dimensions. For example, the request may include "display revenue by product," "display amount of sales per country," or "display revenue for a specific country by product." FIG. **1** shows data **120** being split by product, data and store.

The OLAP operations on the multidimensional data may include slicing, dicing, drill down and drill up, roll-up and pivoting. Slicing may select a subset of a cube by choosing a single value for a dimension. Slicing may create a new object having one dimension less than the previous object. Dicing may select a subset of a cube by choosing multiple values for the dimensions. With dicing the number of dimensions may remain the same but the new object may have less data. The drill down operation may provide the user a more detailed view by breaking up summarized data along the dimensional hierarchy. For example, a user may view sales by continent and then drill down to sales per country or sales per region. The drill up operation may reduce the level of detail by summarizing multiple dimensions into a parent dimensions. The drill up operation may be restricted to summarizing the dimensions that are within the dimensional hierarchy. Similar to drill up operation, the roll up operation may summarize data but may summarize arbitrary dimensions by using, for example, mathematical formulas. The pivoting operation is a visualization operation that allows users to rotate the axes of a cube to see another face of the cube. The above discussed OLAP operations may provide an OLAP cube to be displayed in the decomposition tree according to embodiments of the present disclosure.

FIG. **2** illustrates a user interface **200** displaying a hybrid decomposition tree **210** according to an embodiment of the present disclosure. The hybrid decomposition tree **210** may allow for multiple dimensions of data to be displayed in one level of the decomposition tree and/or for one dimension to be displayed in different levels of the decomposition tree **210**. The user interface **200** may include a palate **210**, a decomposition tree **220** and a node details display **230**. The user interface **200** may be displayed on a display of the client device **102**, **104** and **106**, shown in FIG. **1**.

The palate **210** may provide the user with measures **212** and dimensions **214** that can be assigned to nodes and/or levels of the decomposition tree **210**. The available measures **212** and/or dimensions **214** may be selected by the user and associated with the desired node or level in the decomposition tree **210** by, for example, a drag and drop gesture. The measures **212** and/or dimensions **214** may be associated with a single node by selecting the desired measures **212** and/or dimensions **214** for the node. In one embodiment, the measures **212** and/or dimensions **214** may associated with a selected node by dragging and dropping them on the selected node or they may be associated with all of the selected nodes by dropping the measure **212** or dimension **214** on a portion of a display that does not correspond to a displayed node. The measures **212** may be associated with a level of displayed nodes by associated the measure with a desired level of the decomposition tree **210**. The measures **212** and/or dimensions **214** may also be associated with a node that is selected by a leap controller, a kinect controller, touch screen or other selection methods.

The measures **212** and dimensions **214** displayed in the palate **210** may be the measures **212** and dimensions **214** that are associated with data of an organization or with a specific portion of the data of the organization (e.g., specific multidimensional OLAP cube). The content of the palate **210** may change based on updates to the data and/or selections made by the user in the user interface.

The decomposition tree **220** includes a tree-based layout including data elements that are displayed as nodes of the decomposition tree **220**. The nodes may include a root node which operates as a parent node for a plurality of children nodes. Each child node may be a parent node to a plurality of subsequent children nodes (e.g., great grandchild of the root node). The decomposition tree **220** may include a plurality of levels **222**, **224**, **226** and **228** formed by the nodes. Each level **222**, **224**, **226** and **228** may include one or more nodes. The hierarchy of the nodes between the levels **222**, **224**, **226** and **228** may be visually illustrated by connecting lines.

The nodes in each level **222**, **224**, **226** and **228** may convey a notion of quantity by visual encoding. For example, individual objects such as bars or circles with a portion of the object filled in or colored, differently sized objects, numbers or text within the object, different colors, or symbols may be used to convey the quantity represented by the node. As shown in FIG. **2**, the size or area of the circle representing each node may convey the quantity associated with each node.

When the value of the nodes is displayed via visual encoding, the scaling of the nodes may include global scaling or level scaling. With global scaling the size or area of the object representing each node may be a percentage of the root node (e.g., measure node). With level scaling, a node's size or area may be a percentage of the of the largest sibling node in the group of nodes. Regardless of the type of scaling that is selected, a minimum size of the object may be set to allow nodes with very low values to be easily visible in the decomposition tree **220**.

In another embodiment, sub-tree scaling may allow the user to select one node to which the largest radius is assigned and the children nodes of the selected node may be rescaled based on the selected node. The remaining nodes (e.g., nodes not included in the sub-tree selected) may be scaled to have a minimum size (e.g., minimum radius).

Each level **222**, **224**, **226** and **228** of the decomposition tree **220** may include nodes that belong to more than one splitting dimension. In one embodiment, a node in one level may be split up by different dimensions simultaneously to provide a next level with multiple dimensions. For example, as shown in FIG. **2**, the Colorado node from level **226** may be split to provide level **228** that includes nodes split by a product dimension (e.g., computer, camera, television and audio) and nodes split by a year dimension (e.g., **2007**, **2008** and **2009**). Thus, single level **228** includes nodes that are split by more than one dimension.

In another embodiment, a plurality of nodes in one level may be split according to different dimensions. For example, as shown in FIG. **2**, level **226** may include nodes that are split by state dimension (e.g., Texas, Colorado and Alaska) from the United States node in level **224** and may include nodes that are split by product dimension (e.g., computer, camera, television and audio) from the Canada node in level **224**. In one embodiment, each node in one level may be split according to different dimensions.

As shown in FIG. **2**, some nodes may not be split. The user may select which nodes should be split by desired dimensions while other nodes are shown without being split by any dimensions. This may allow for the nodes to be displayed with the desired detail while avoiding the clutter of information that is not needed to make a business decision.

The user interface **200** may display the relationship of each node to the preceding nodes (e.g., relationship of parent nodes to child nodes). The visual encoding of the tree may display to which dimension each group of nodes belongs. In FIG. **2** this is shown with lines linking the nodes. In other embodiments, color or shape of the nodes may be used to show groups of nodes that are split by the same dimension. For example, all of the nodes that are split by the type of product may be color coded with the same color. In other embodiments, grouping clusters or instances of one dimension together may visually convey the relationship of the nodes.

The nodes in the decomposition tree **220** representing instance value of a dimension may be used to split other nodes by the associated dimension. For example, a node representing Audio, which is an instance value of the product dimension, may be used in the same way as the product dimension from the palate **210**. Thus, as illustrated by line **264** a user may drag the node representing Audio, to another node (e.g., Canada node) in the decomposition tree **220** to split the node by the product dimension. In the same way, as represented by line **262**, the user may drag the product dimension in the palate **210** to the Canada node to split the Canada node by the product.

The nodes of the decomposition tree **220** may be sorted based on the node properties (e.g., values of the node or dimension values). In one embodiment, a specific level or group of nodes may be arranged in order based on the value represented by each node. For example, as shown in FIG. **2**, the nodes in level **226** may be arranged in descending order from top to bottom of the display. The Texas node with a larger value may be displayed first with a larger circle and the Alaska node with a smaller value may be displayed last with a smaller circle. In other embodiments, the nodes in a specific group or level of the decomposition tree **220** may be sorted by the name of the node (e.g., alphabetical or numerical order). For example, as shown in FIG. **2**, the nodes corresponding to the year in level **228** are arranged in ascending order.

The value of the node may be included as part of the node (e.g., US node and Texas node) or the value of the node may be provided in a separate dialog box **230**. The dialog box **230** may include one or more of the node name, node value, dimension by which the node is split, the dimensions by which the node may be further split, when the value was updated, statistics on the value of the node and trend of the node value. The dialog box **230** may be displayed in response to a request by the user (e.g., clicking gesture or gesture putting cursor or finger over the node for which the details are to be displayed).

The nodes in the decomposition tree **220** may be directly manipulated. As discussed above, a dimension may be assigned to a node by dragging the dimension from the palate **210** to a destination node. The destination node becomes the parent of a new level of analysis nodes for the assigned dimension. Similarly, if a node is assigned to another node by dragging an instance node onto a destination node, the destination node may become the parent of a new level of analysis nodes. The dimension of the split may be the same as the dimension of the instance node that is dragged onto the destination node.

The nodes may be assigned a measure **212**. Different measures **212** may be assigned to different nodes. If a node is assigned a specific measure, the nodes that are emanating from the node may be assigned the same measure. Multiple measures **212** may be assigned to each node. Thus, multiple measures **212** may be displayed in the same view. If a certain measure is assigned to the decomposition tree or a portion of the decomposition tree **220**, a new measure may be applied to the decomposition tree **220** of a portion of the decomposition tree **220** by dragging a new measure from the palette **210** to the nodes of the decomposition tree **220**.

The user interface **200** may include a plurality of user controls to control the way the decomposition tree is displayed. The user controls may include one or more of reset **242**, collapse all **244**, filter **246**, zooming options **248** and display type **250**. The reset **242** may provide the use with option to reset the display of the decomposition tree **220**. When activated, the reset control **242** may remove the display of all of the levels of the decomposition tree. In another embodiment, the reset control **242** may remove the display of all of the levels of the decomposition tree **220** with the exception of the first level (e.g., level **222**).

The collapse all control **244** may collapse all of levels of the decomposition tree **220**. The collapse all control **244** does not remove the dimensions that are selected in the levels but may hide the display of selected dimensions in the levels of the decomposition tree. In another embodiment, the user may have an option to collapse one or more portions of the decomposition tree **220** by selecting a node and picking an option to collapse all of the nodes that are derived from the selected node. The collapse option may allow the user to collapse sections of the decomposition tree **220** that are not needed by the user to make a decision. When the collapsed section of the decomposition tree **220** are needed again by the user, the user may request that all or a portion of the collapsed sections of the decomposition tree **220** are displayed again.

The filter option **246** may filter the data that is displayed in the nodes. For example, the filter option may select not to display data associated with specific dimensions, not to display data with values that exceed a preset value, not to display data with values that are below a preset value, not to display data with values that change more than a desired frequency, to display data that is associated only with a certain dimension, or to display data that changes at a predetermined frequency. The filter **246** may be applied after the decomposition tree **220** is displayed with the selected dimensions. Setting the filter **246** may update the display of the decomposition tree **220** with data based on the setting made in the filter **246**.

The zooming option **248** may zoom in, zoom out and pan across the decomposition tree **220**. The zooming option **248** may be used when a user wants to closely examine a portion of the decomposition tree or when the size of the decomposition tree exceeds a size that can be easily displayed in the available display.

The display type control **250** may provide user with different options of how to render the decomposition tree **220**. The display type control **250** may include selecting the type of objects (e.g., circle or squares) used to represent the nodes, the colors and shading of the nodes, how values are represented in the nodes, how the interconnections between the nodes are shown and the rendering of the decomposition tree **220** (e.g., left to right, right to left, top to bottom or polar rendering, discussed below).

A plurality of decomposition trees **220** may be displayed simultaneously. In one embodiment, a user may copy a generated decomposition tree **220** and display the copied decomposition tree **220** with a different measure. The copied decomposition tree may have the same displayed hierarchy and dimensions as the original decomposition tree.

FIG. **3** illustrates a method **300** of displaying a decomposition tree according to an embodiment of the present disclosure. The method **300** may include displaying a parent node based on selections made by a user **310**, displaying children nodes based on selections made by the user **320**, and displaying grandchildren nodes based on selections made by the user **330**. While not shown in FIG. **3**, the method **300** may include displaying additional nodes (e.g., great-grandchildren nodes) in additional levels of the decomposition tree.

Displaying the parent node based on selections made by a user **310** may include creating a parent node, accessing the data associated with the parent node and rendering the rood node in the decomposition tree based on the data associated with the parent node. The parent node may be displayed based on the measure selected by the user. The measure may be selected from a palate displaying the available measures. The parent node may be displayed in a first level of the decomposition tree.

Displaying the children nodes based on selections made by the user **320** may include receiving instructions from the user to split the parent node by one or more dimension. Displaying the children nodes may include creating the children nodes, accessing the data associated with the children nodes and rendering the children nodes in the decomposition tree based on the data associated with the children nodes. The children nodes may be displayed as groups of nodes, each group of nodes representing one of the selected dimensions. The parent node may be split by a first dimension and by a second dimension, which is different from the first dimension **322**. The children nodes may be displayed in a second level of the decomposition tree. Thus, the nodes provided along the first dimension and the nodes provided along the second dimension may be provided in the same level (e.g., second level) of the decomposition tree.

Displaying the grandchildren nodes based on selections made by the user **330** may include receiving instructions from the user to split one or more of the children node by one or more dimension. Displaying the grandchildren nodes **330** may include creating the grandchildren nodes, accessing the data associated with the grandchildren nodes and rendering the grandchildren nodes in the decomposition tree based on the data associated with the grandchildren nodes. The grandchildren nodes may be displayed as groups of nodes, each group of nodes representing one of the selected dimensions. One of the children nodes may be split by a first dimension and by a second dimension, which is different from the first dimension **332**. One of the children nodes may be split by a first dimension and another children node may be split by a second dimension **334**. The grandchildren nodes may be displayed in a third level of the decomposition tree. Thus, the nodes provided along the first dimension and the nodes provided along the second dimension may be provided in the same level (e.g., third level) of the decomposition tree.

The method **300** may include displaying groups of nodes that are split by the same dimension on different levels of the decomposition tree. For example, a node in the second level of the decomposition tree may be split by a particular dimension and a node in a third level may also be split by the same particular dimension.

Displaying the nodes in steps **310-340** may include rendering the nodes and connections between the nodes to provide a visual representation of the values represented by the nodes and/or the hierarchy between the nodes.

In FIG. **2**, the decomposition tree is shown with the hierarchy being rendered from left to right. In other embodiments, the decomposition tree may be rendered with the hierarchy being shown from right to left, from top to bottom, or from bottom to top of the display screen. Changes in the orientation of the screen displaying the decomposition tree may automatically change the way the decomposition tree is displayed based on the available space in the display. The top to bottom rendering may be used when the display is provided with a portrait orientation. The user may select the type of rendering that is used to display the decomposition tree.

FIGS. **4**A and **4**B illustrate a linear decomposition tree **410** and a polar decomposition tree **450** according to an embodiment of the present disclosure. The linear decomposition tree **410** may be rendered as a polar (e.g., circular) decomposition tree **450**. In the linear decomposition tree **410** the x-coordinate **412** may define the multiple levels within the tree and the γ-coordinate **414** may define the groups of nodes split by the respective dimension. In the polar decomposition tree **450** the radius **452** from the center **454** (e.g., root node) of the polar decomposition tree **450** may define the multiple levels with the tree and the perimeter **456** of the decomposition tree at each radius may define the groups of nodes split by the respective dimension. The polar decomposition tree **450** may be used when a large number of nodes need to be displayed in each level.

The front end of the application providing the decomposition tree according to the present disclosure may be written in JavaScript, for example using User Interface Development Kit for HTML5 (SAP® UI5), but is not so limited. The back end of the application may use SAP® Analytics on Demand (AoD), where OLAP data is supplied by AoD, but is not so limited.

Some embodiments may include the above-described methods being written as one or more software components. These components, and the functionality associated with each, may be used by client, server, distributed, or peer computer systems. These components may be written in a computer language corresponding to one or more programming languages such as, functional, declarative, procedural, object-oriented, lower level languages and the like. They may be linked to other components via various application programming interfaces and then compiled into one complete application for a server or a client. Alternatively, the components maybe implemented in server and client applications. Further, these components may be linked together via various distributed programming protocols. Some example embodiments may include remote procedure calls being used to implement one or more of these components across a distributed programming environment. For example, a logic level may reside on a first computer system that is remotely located from a second computer system containing an interface level (e.g., a graphical user interface). These first and second computer systems can be configured in a server-client, peer-to-peer, or some other configuration. The clients can vary in complexity from mobile and handheld devices, to thin clients and on to thick clients or even other servers.

The above-illustrated software components are tangibly stored on a computer readable storage medium as instructions. The term "computer readable storage medium" should be taken to include a single medium or multiple media that stores one or more sets of instructions. The term "computer readable storage medium" should be taken to include any physical article that is capable of undergoing a set of physical changes to physically store, encode, or otherwise carry a set of instructions for execution by a computer system which causes the computer system to perform any of the methods or process steps described, represented, or illustrated herein. Examples of computer readable storage media include, but are not limited to: magnetic media, such as hard disks, floppy disks, and magnetic tape; optical media such as CD-ROMs, DVDs and holographic devices; magneto-optical media; and hardware devices that are specially configured to store and execute, such as application-specific integrated circuits ("ASICs"), programmable logic devices ("PLDs") and ROM and RAM devices. Examples of computer readable instructions include machine code, such as produced by a compiler, and files containing higher-level code that are executed by a computer using an interpreter. For example, an embodiment of the disclosure may be implemented using Java, C++, or other object-oriented programming language and development tools. Another embodiment of the disclosure may be implemented in hard-wired circuitry in place of, or in combination with machine readable software instructions.

FIG. **5** is a block diagram of an exemplary computer system **500**. The computer system **500** includes a processor **505** that executes software instructions or code stored on a computer readable storage medium **555** to perform the above-illustrated embodiments of the disclosure. The computer system **500** includes a media reader **540** to read the instructions from the computer readable storage medium **555** and store the instructions in storage **510** or in random access memory (RAM) **515**. The storage **510** provides a large space for keeping static data where at least some instructions could be stored for later execution. The stored instructions may be further compiled to generate other representations of the instructions and dynamically stored in the RAM **515**. The processor **505** reads instructions from the RAM **515** and performs actions as instructed. According to one embodiment of the disclosure, the computer system **500** further includes an output device **525** (e.g., a display) to provide at least some of the results of the execution as output including, but not limited to, visual information to users and an input device **530** to provide a user or another device with means for entering data and/or otherwise interact with the computer system **500**. Each of these output devices **525** and input devices **530** could be joined by one or more additional peripherals to further expand the capabilities of the computer system **500**. A network communicator **535** may be provided to connect the computer system **500** to a network **550** and in turn to other devices connected to the network **550** including other clients, servers, data stores, and interfaces, for instance. The modules of the computer system **500** are interconnected via a bus **545**. Computer system **500** includes a data source interface **520** to access data source **560**. The data source **560** can be accessed via one or more abstraction layers implemented in hardware or software. For example, the data source **560** may be accessed by network **550**. In some embodiments the data source **560** may be accessed via an abstraction layer, such as, a semantic layer.

A data source is an information resource. Data sources include sources of data that enable data storage and retrieval. Data sources may include databases, such as, relational, transactional, hierarchical, multi-dimensional (e.g., OLAP), object oriented databases, and the like. Further data sources include tabular data (e.g., spreadsheets, delimited text files), data tagged with a markup language (e.g., XML data), transactional data, unstructured data (e.g., text files, screen scrapings), hierarchical data (e.g., data in a file system, XML data), files, a plurality of reports, and any other data source accessible through an established protocol, such as, Open DataBase Connectivity (ODBC), produced by an underlying software system (e.g., ERP system), and the like. Data sources may also include a data source where the data is not tangibly stored or otherwise ephemeral such as data streams, broadcast data, and the like. These data sources can include associated data foundations, semantic layers, management systems, security systems and so on.

A semantic layer is an abstraction overlying one or more data sources. It removes the need for a user to master the various subtleties of existing query languages when writing queries. The provided abstraction includes metadata description of the data sources. The metadata can include terms meaningful for a user in place of the logical or physical descriptions used by the data source. For example, common business terms in place of table and column names. These terms can be localized and or domain specific. The layer may include logic associated with the underlying data allowing it to automatically formulate queries for execution against the underlying data sources. The logic includes connection to, structure for, and aspects of the data sources. Some semantic layers can be published, so that it can be shared by many clients and users. Some semantic layers implement security at a granularity corresponding to the underlying data sources' structure or at the semantic layer. The specific forms of semantic layers includes data model objects that describe the underlying data source and define dimensions, attributes and measures with the underlying data. The objects can represent relationships between dimension members, provides calculations associated with the underlying data.

In the above description, numerous specific details are set forth to provide a thorough understanding of embodiments of the disclosure. One skilled in the relevant art will recognize, however that the various embodiments can be practiced without one or more of the specific details or with other methods, components, techniques, etc. In other instances, well-known operations or structures are not shown or described in detail to avoid obscuring aspects of the disclosure.

Although the processes illustrated and described herein include series of steps, it will be appreciated that the different embodiments of the present disclosure are not limited by the illustrated ordering of steps, as some steps may occur in different orders, some concurrently with other steps apart from that shown and described herein. In addition, not all illustrated steps may be required to implement a methodology in accordance with the present disclosure. Moreover, it will be appreciated that the processes may be implemented in association with the apparatus and systems illustrated and described herein as well as in association with other systems not illustrated.

The above descriptions and illustrations of embodiments of the disclosure, including what is described in the Abstract, is not intended to be exhaustive or to limit the embodiments to the precise forms disclosed. While specific embodiments of, and examples for, the embodiments are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the disclosure, as those skilled in the relevant art will recognize. These modifications can be made to the embodiments in light of the above detailed description.

We claim:

1. A computer implemented method for displaying multidimensional data, the method being implemented by one or more data processors forming part of at least one computing device and comprising:

displaying, by at least one data processor in a graphical user interface, a decomposition tree including a plurality of levels, a first level including a parent node representing data with a measure along multiple dimensions and other levels including one or more child nodes that represent a subset of the data represented by the parent node along dimensions selected by a user, wherein the child nodes are displayed along a same dimension at different levels of the decomposition tree;

in response to the user applying a first splitting dimension and a second splitting dimension to a first selected node and a second selected node, displaying, by at least one data processor in the graphical user interface, in a next level following a level with the first selected node and a second selected node, one or more nodes along the first splitting dimension and one or more nodes along the second splitting dimension, wherein the one or more nodes along the first and second splitting dimensions are intersecting datasets and the user applies the first splitting dimension and the second splitting dimension to the first selected node by dragging the first and second splitting dimensions to the first selected node from a palate displaying available dimensions and the user applies the first splitting dimension and the second splitting dimension to the second selected node by dragging the first selected node in the decomposition tree to the second selected node, wherein the applied first splitting dimension and the applied second splitting dimension of the first selected node are applied to the second selected node and remain applied to the first selected node;

rendering, by at least one data processor in the graphical user interface, objects representing the parent node and the child nodes to graphically illustrate values represented by the nodes; and

rendering, by at least one data processor in the graphical user interface, connections representing the relationship between the parent node and the child nodes.

2. The computer implemented method of claim **1**, wherein each node is illustrated by an object having at least a minimum size and the value represented by the node is presented by visually encoding the object.

3. The computer implemented method of claim **1**, wherein each node is illustrated by a circle having at least a minimum radius and the value represented by the node corresponds to a size of the circle.

4. The computer implemented method of claim **1**, wherein at least one node represents a plurality of measures.

5. The computer implemented method of claim **1**, further comprising, in response to user selections, collapsing, by at least one data processor in the graphical user interface, a portion of the decomposition tree.

6. The computer implemented method of claim **1**, further comprising, in response to the user applying the first splitting dimension to the first selected node and applying the second splitting dimension to the second selected node, the first and second selected nodes being in the same level, displaying in the level following the level including the first and second selected nodes one or more nodes along the first splitting dimension from the first selected node and one or more nodes along the second splitting dimension from the second selected node.

7. The computer implemented method of claim **1**, wherein the parent node is split by multiple dimensions in a level following the level of the parent node.

8. A non-transitory computer readable medium containing program instructions from providing a user interface with multi-dimensional data on a user device, wherein execution of the program instructions by one or more processor of a computer system causes one or more processors to carry out the steps of:

displaying a decomposition tree including a plurality of levels, a first level including a parent node representing data with a measure along multiple dimensions and other levels including one or more child nodes that represent a subset of the data represented by the parent node along dimensions selected by a user;

rendering objects representing the parent node and the child nodes to graphically illustrate values represented by the nodes;

rendering connections representing the relationship between the parent node and the child nodes; and

in response to the user applying a first splitting dimension and a second splitting dimension to a first selected node and a second selected node, the first and second selected nodes being in the same level, displaying in the level following the level including the first and second selected nodes, one or more nodes along the first splitting dimension and one or more nodes along the second splitting dimension, wherein the one or more nodes along the first and second splitting dimensions are intersecting datasets and the user applies the first and second splitting dimensions to the first selected node by dragging the first and second dimensions from a palate displaying available dimensions and the user applies the first and second splitting dimensions to the second selected node by dragging the first selected node in the decomposition tree to the second selected node, wherein the applied first splitting dimension and the applied second splitting dimension of the first selected node are applied to the second selected node and remain applied to the first selected node.

9. The non-transitory computer readable medium of claim **8**, wherein each node is illustrated by an object having a minimum size and the value represented by the node is represented by visually encoding the object.

10. The non-transitory computer readable medium according to claim **8**, wherein at least one node represents a plurality of measures.

11. The non-transitory computer readable medium according to claim **8**, wherein the user applies at least one of the first splitting dimension to the first selected node and the second splitting dimension for the second selected node by applying another node in the decomposition tree to one of the first and second selected nodes.

12. The non-transitory computer readable medium according to claim **8**, further comprising, in response to user selections, displaying in multiple levels one or more nodes along a same dimension.

13. The non-transitory computer readable medium according to claim **8**, further comprising, in response to a user selection, collapsing a portion of the decomposition tree.

14. The non-transitory computer readable medium according to claim **8**, further comprising, in response to the user applying a third splitting dimension and a fourth splitting dimension to a third selected node, displaying in a next level following the level with the third selected node, one or more nodes along the third splitting dimension and one or more nodes along the fourth splitting dimension.

15. The computer implemented method of claim **1**, wherein the user applies at least one of the first splitting dimension and the second splitting dimension to a selected node by dragging one of the first splitting dimension and the second splitting dimension from the palate displaying available dimensions, wherein one of the applied first splitting dimension and the applied second splitting dimension are retained within the palate displaying available dimensions.

16. A system for displaying multi-dimensional data, the system comprising:

at least one data processor;

memory storing instructions which, when executed by the at least one data processor, result in operations comprising:

displaying, in a graphical user interface, a decomposition tree including a plurality of levels, a first level including a parent node representing data with a measure along multiple dimensions and other levels including one or more child nodes that represent a subset of the data represented by the parent node along dimensions selected by a user, wherein the child nodes are displayed along a same dimension at different levels of the decomposition tree;

in response to the user applying a first splitting dimension and a second splitting dimension to a first selected node and a second selected node, displaying the graphical user interface, in a next level following a level with the first selected node and a second selected node, one or more nodes along the first splitting dimension and one or more nodes along the second splitting dimension, wherein the one or more nodes along the first and second splitting dimensions are intersecting datasets and the user applies the first splitting dimension and the second splitting dimension to the first selected node by dragging the first and second splitting dimensions to the first selected node from a palate displaying available dimensions and the user applies the first splitting dimension and the second splitting dimension to the second selected node by dragging the first selected node in the decomposition tree to the second selected node, wherein the applied first splitting dimension and the applied second splitting dimension of the first selected node are applied to the second selected node and remain applied to the first selected node;

rendering, in the graphical user interface, objects representing the parent node and the child nodes to graphically illustrate values represented by the nodes; and

rendering, in the graphical user interface, connections representing the relationship between the parent node and the child nodes.

17. The system of claim **16**, wherein each node is illustrated by an object having at least a minimum size and the value represented by the node is presented by visually encoding the object.

18. The system of claim **16**, wherein each node is illustrated by a circle having at least a minimum radius and the value represented by the node corresponds to a size of the circle.

19. The system of claim **16**, wherein at least one node represents a plurality of measures.

20. The system of claim **16**, wherein the parent node is split by multiple dimensions in a level following the level of the parent node.

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